DO EQUIVALENCE CLASSES MEDIATE EXTENSIONS OF STIMULUS FUNCTION?

By

MANISH VAIDYA

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
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DOCTOR OF PHILOSOPHY

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Stimulus equivalence is demonstrated when the functions of stimuli established in reinforced conditional discrimination trials are shown to be interchangeable in unreinforced conditional discrimination trials involving the same stimuli in novel configurations. Although much has been learned about equivalence relations, the preparations typically used have not allowed a precise understanding of the relationship between trained and derived conditional relations or the role of equivalence classes in more complex behavioral relations. The purpose of Experiment 1 was to attempt a more precise understanding of the relationship between the acquisition of trained conditional discriminations and the emergence of untrained conditional discriminations. Six undergraduate students were exposed to 18 conditional discrimination trial types designed to train and test for 3 3-member equivalence classes from the beginning of the experiment. Once choices were stable, the contingencies for 2 of 6 trained relations were reversed. The results showed that there was a lag between the acquisition of the trained conditional relations and the emergence of derived conditional relations that define equivalence classes. In addition, the reversal of contingencies for a subset of the trained original relations produced changes on some of the derived conditional discriminations but not others. These data suggested that (a) the behavioral prerequisites for conditional relations and equivalence relations are not identical and (b) the different stimulus control relations that define an equivalence relation can vary independent of one another. The purpose of Experiment 2 was to ascertain the role of equivalence classes in the extension of stimulus functions across class members. Three undergraduate students were exposed to the conditional discrimination task described above with a successive simple discrimination task interlaced throughout the session from the beginning of the experiment. The results showed that extension of stimulus function was sometimes (a) observed prior to the development of equivalence relations and (b) not observed despite the formation of equivalence relations. These data suggest that equivalence classes are neither necessary nor sufficient for the extension of stimulus functions. Taken together, these results call into question the assumed integrated nature of equivalence relations and their role in the extension of stimulus functions.

GENERAL INTRODUCTION

Some of the oldest questions in psychology pertain to reference and meaning. How, for example, do symbols come to represent, or refer to, other figures, objects, or events? Early behaviorist accounts suggested simple substitution as the answer. A symbol was said to mean the same thing as its referent to the extent that symbol and referent produced the same kind of behavior. As Watson (1924) put it:

> [w]ords not only can and do call out other words, phrases and sentences, but when the human being is properly organized they can call out all of his manual activity. The words function in the manner of calling out responses exactly as did the objects for which the words serve as substitutes (p. 233).

Although current approaches no longer assume that reference-like relations involve the complete substitutability of symbols for objects or events, the fundamental problem of reference and meaning has scarcely been resolved. The key issue, as Watson recognized, lies with the extension of stimulus function, or the circumstances in which a neutral stimulus may come to function in a manner similar to an already established stimulus without direct training.

Some important conceptual and empirical advances in the study of untrained extensions of stimulus function have come from an area known as _stimulus equivalence_ (Sidman, 1971, 1994). Briefly, research in stimulus equivalence is concerned with the study of the origin, maintenance, and modification of behavior under control of relations between stimuli. The experimental preparation used to investigate equivalence relations generally involves a conditional discrimination procedure in which a subject chooses one of several available stimuli (called comparison stimuli) conditionally upon the presence of another stimulus (called the sample stimulus). Choosing the experimenter-designated "correct" comparison produces a reinforcing consequence whereas choosing any other comparison ends the trial without reinforcement. A subject is explicitly taught several interrelated conditional discriminations (e.g., given A1 pick B1, not B2 or B3; given B1 pick C1, not C2 or C3) and then tested for the emergence of other conditional discriminations that were not directly trained (e.g., given B1 pick A1, not A2 or A3; given C1 pick B1, not B2 or B3; given A1 pick C1, not C2 or C3; and given C1 pick A1, not A2 or A3). Accurate performance on these novel conditional discriminations, in the absence of reinforcement, is said to indicate the existence of an equivalence relation among the stimuli (Sidman & Tailby, 1982).

These stimulus-equivalence relations are defined in terms of 3 properties that define equivalent sets in mathematics--reflexivity, symmetry and transitivity (Sidman & Tailby, 1982). The property of reflexivity is seen when a subject selects comparison stimuli that are physically identical to the sample stimuli. For example, given training to pick A1 given A1, a subject picks B1 given B1 without reinforcement for doing so. The property of symmetry is seen when the sample and comparison functions of stimuli become interchangeable. For example, given a history of reinforcement for selecting B1 given A1 as sample, a subject selects A1 given B1 as a sample without reinforcement for doing so. The property of transitivity is seen when the sample from one conditional discrimination exerts conditional control over the selection of a comparison from a different, but related, conditional discrimination. For example, given a history of selecting B1 given A1 and selecting C1 given B1, a subject selects C1 given A1 as the sample. These relationships are illustrated schematically in Figure 1.

This three-part definition has been extremely important in establishing a clear matrix of behavioral tasks that can be used to indicate the presence or absence of equivalence relations among the stimuli. As an example, consider an experiment reported by Sidman (1971). Using a slightly different training structure, a developmentally delayed subject was trained to select a picture of a cat (B1) given the spoken word "cat" (A1) and to select the written word CAT (C1) given the spoken word "cat" (A1). As a result of this training the subject came to respond accurately on other conditional discriminations that had not been directly trained. For example, it was found that the subject could now select the picture of a cat (B1) given the written word CAT (C1) as a stimulus and select the written word CAT (C1) given the picture of a cat (B1). Sidman (1971) concluded that, by virtue of the conditional discrimination training, the stimuli had become substitutable or "equivalent" within the context of the conditional discrimination procedure.

An important feature of these stimulus-equivalence classes is the demonstration that stimuli that become equivalent in the context of a conditional discrimination task can also become equivalent in other contexts. Based on the observation that stimulus functions extend across members of equivalence classes, it has been suggested that the context of stimulus equivalence experiments may serve as a useful laboratory analogue for the study of extensions of stimulus functions in natural languages, providing a potential basis for the experimental analysis of reference and meaning (Hayes, 1992; Sidman, 1986). It is important to note that if the stimuli related via equivalence relations did not also begin to share

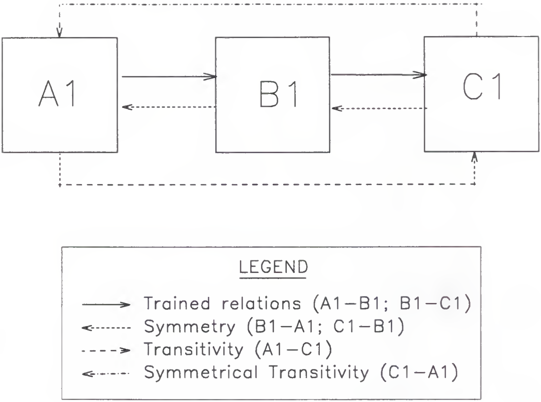

A1
B1
C1
LEGEND
Trained relations (A1—B1; B1—C1)
Symmetry (B1—A1; C1—B1)
Transitivity (A1—C1)
Symmetrical Transitivity (C1—A1)

Figure 1. A schematic representation of the properties that define an equivalence relation. The solid lines indicate trained relations and the broken lines indicate derived relations.

established stimulus functions they would be of little use as laboratory analogues of symbolic relations. For example, if the words "water," "agua," and "paanee" entered into equivalence classes without also beginning to share stimulus functions, then their being equivalent would only be meaningful in terms of the derived conditional discriminations used to document the equivalence relations. It is, however, precisely the observation that stimuli related via equivalence also begin to share stimulus functions that has suggested that the functions of the stimuli in equivalence experiments may be likened to the functions of symbols in natural languages (Hayes, 1992; Sidman, 1986).

These observations, in combination with the fact that equivalence class formation has not yet been reported with pre verbal humans or non humans (Devany, Hayes, & Nelson, 1986; Sidman, et al., 1982) but (see Schusterman & Kastak, 1993), have led many to conclude that equivalence-like relations may be fundamentally related to symbolic or linguistic functioning (Hayes & Hayes, 1989; Sidman, 1994). It has further been suggested that research on the extension of stimulus function via equivalence classes may yield some insights about how humans come to behave systematically and predictably in the presence of circumstances that have never before been experienced (Hayes, 1992; Sidman, 1986).

Although some research has examined the extension of respondent eliciting functions (e.g., Dougher, Auguston, Markham, & Greenway, 1994) and operant consequence functions (e.g., Hayes, Kohlenberg, & Hayes, 1991), the majority of work in this area has been concerned with the transfer of discriminative stimulus functions (e.g., Auguston & Dougher, 1997; Barnes, Browne, Smeets, & Roche, 1995; Lazar, 1977; Lazar & Kotlarchyk, 1982; Wulfert & Hayes, 1988). The earliest experiment explicitly concerned with transfer of function and stimulus equivalence was reported by Lazar (1977). Adult subjects were asked to point to each member of several pairs of stimuli across repeated trials. Two distinct classes of stimuli (roughly, "pointed-to first" and "pointed-to second") emerged from this training. In the next phase, the same stimuli served as samples in a conditional discrimination task in which novel stimuli were introduced as comparisons in reinforced trials. Following that, conditional discrimination trials were presented in which the novel stimuli served as samples ("incorrect" responses during this condition were remediated with direct training). Finally, the sequence test was re-presented with the novel stimuli to test for transfer of function. Lazar (1977) reported that 2 of the 3 subjects responded appropriately. That is, these subjects pointed to the novel stimulus that was placed in the "first" class first and the "second" class second. The discriminative properties of the training stimulus had thus extended to other stimuli in the same equivalence class.

Studies have also examined the extension of other kinds of discriminative functions. Catania, Horne, and Lowe (1989) established a high response rate in the presence of one stimulus (a tree) and a low response rate in the presence of a different stimulus (a star) in a 5-year-old child. The schedules and stimuli alternated several times within a session in a multiple schedule arrangement. In the next phase, these stimuli were used as comparisons in conditional discrimination trials involving two novel stimuli as samples (a worm and a block). After several sessions of greater than 90% correct matches and consistent rate differences in the multiple schedule, the subject was re-exposed to the multiple schedule with the difference that the novel figures served as component-correlated stimuli. The subject's performance in the presence of the novel figures was similar to the performance in the presence of the original figures suggesting that the trained discriminative functions of the original stimuli had extended to the novel stimuli. Finally, match-to-sample trials with the novel stimuli serving as samples demonstrated that the conditional and discriminative functions of the stimuli in the trained conditional discriminations were, in fact, reversible--an outcome consistent with the definition of the property of symmetry (Sidman & Tailby, 1982).

A similar study was reported by Barnes and Keenan (1993). These researchers first established four conditional discriminations (given A1 pick B1, given B1 pick C1, given A1 pick C1, and given A2 pick C2). In the next phase, a high response rate was established in the presence of B2 and a low response rate was established in the presence of B1. Tests of extension of function revealed that all subjects responded at high rates in the presence of C2 and low rates in the presence of C1. Thus, the discriminative functions explicitly established for B1 and B2 had extended to C1 and C2. Again, match-to-sample test trials demonstrated that the conditional and discriminative functions of the stimuli involved in the trained conditional discriminations had become reversible.

These studies have contributed to our understanding of the relationship between equivalence classes and the extension of stimulus functions. They show that a variety of stimulus functions can extend across equivalence classes in the absence of direct contingencies supporting such extensions. The train-and-test method characteristic of traditional preparations, however, has not allowed a precise understanding of the role of equivalence class formation in the extension of stimulus functions. The traditional preparation typically involves four phases presented at different times during the experiment in which (a) original relations are trained, (b) the development of equivalence relations is tested, (c) a particular function is established for one of the stimuli in the equivalence class, and (d) the emergent extension of that function is tested.

One problem with these methods is that they do not permit a precise identification of the relationship between the development of equivalence classes and the observed extension of stimulus functions. For example, the temporal relationship between the extension of stimulus function and the development of equivalence relations is not very well understood. Do the stimulus functions extend before, during, or after equivalence class formation? Conversely, do equivalence classes form before, during, or after the extension of stimulus functions? Answers to these questions may also inform other substantive issues. Is the formation of an equivalence class and the extension of stimulus function related to the same process? Would a lag in the extension of stimulus function suggest two separate processes? What is required to answer these kinds of questions is a procedure in which the development of equivalence classes and the extension of stimulus functions can be tracked together over time.

One of the more immediate obstacles toward an identification of the relationship between equivalence class formation and the extension of functions is our limited understanding of the relationship between the acquisition of the original (trained) conditional discriminations and the development of equivalence relations among stimuli. Although the trained conditional discriminations are the theoretical basis for the development of equivalence relations among stimuli (Sidman, 1986), no specific information is available on their role in the formation of equivalence classes (see Pilgrim & Galizio, 1997). For example, it is not yet well understood when, in relation to the acquisition of the original relations, accurate responding on novel conditional discriminations occurs. If the obtained conditional discriminations are controlled by a single "equivalence" relation among the stimuli (Sidman, 1994) one might expect (a) the derived relations to emerge together following the acquisition of the original relations and (b) all of the derived relations to be disrupted in a similar manner given changes in the original relations on which they are based.

One procedure designed to increase our understanding of the relationship between original relations and equivalence relations involves modifying the original contingencies after equivalence classes have been established (Pilgrim & Galizio, 1990, 1995, 1997; Pilgrim, Chambers, & Galizio, 1995; Saunders, Saunders, Kirby, & Spradlin, 1988; Spradlin, Cotter, & Baxley, 1973). This procedure allows us to determine whether performance on the derived trial types remains dependent on the original relations after equivalence class formation or becomes independent of them. In other words, does changing the original relations after equivalence class formation disrupt performance on all trial types or does it disrupt only those trials involving stimuli that explicitly participated in the changed contingencies?

In sum, although the research to date suggests that equivalence class formation and extension of stimulus function are related, an unequivocal demonstration of the nature of the dependency between the two phenomena has not been forthcoming. One reason may be our limited understanding of the relationship between the different stimulus control relations involved in (a) the acquisition of trained relations, (b) the development of equivalence relations, (c) the establishment of stimulus functions, and (d) the extension of those functions to stimuli in the same equivalence class. What is required to answer questions about the dependencies among these phenomena is a procedure in which the different stimulus control relations that comprise stimulus-equivalence and extension-of-function preparations can be tracked together over time. To that end, the two experiments reported here attempted to track the development of equivalence classes in relation to the acquisition of original relations (Experiment 1) and then use these procedures to track the relationship between the development of equivalence classes and the extension of trained stimulus functions (Experiment 2).

EXPERIMENT 1

The purpose of the current experiment was to develop a method for precisely relating the acquisition of the trained relations to the development of equivalence relations among the stimuli. Several modifications were built into the procedure to permit a more complete description of the specific stimulus control relations involved and the order in which they develop. First, to more precisely relate the acquisition of the original relations to the emergence of equivalence relations, the two types of conditional discrimination trials (training and testing) were presented in blocks of interlaced trials from the beginning of the experiment. Second, the original relations were trained using a variation of Touchette's (1971) procedure for pinpointing the moment of extension of stimulus control. This procedure was originally used to train simple form discriminations to three severely retarded subjects. Subjects were first taught to respond to only one of two simultaneously available hues. Once this discrimination was acquired, the simple form stimuli to be discriminated were presented in the foreground with the colors serving as background. Responding to the S+ compound (form + hue) delayed the onset of the hue background by 500 milliseconds (ms) on the next trial. The point at which subjects began to respond to the form stimulus prior to the onset of the prompt (hue background) was considered the moment of stimulus control extension (Touchette, 1971). In the current experiment, this procedure was modified slightly to pinpoint the moment of conditional-discrimination acquisition. Together, these procedural modifications permitted a more detailed characterization of the relations between trained and derived conditional discriminations than has been possible in past research. Because the procedures depart from the conventional train-and-test methods, a more specific objective of Experiment 1 was to demonstrate that findings typical of more standard stimulus equivalence procedures would be obtained before moving onto the more complex task (taken up in Experiment 2) of relating equivalence to extension of stimulus function.

Method

Subjects

Three male and three female undergraduate students from the University of Florida participated. Subjects were recruited via advertisements placed in the campus newspaper and were selected on the basis of availability and lack of familiarity with behavior analysis. The durations of the subjects' participation ranged from 11 to 32 sessions. Their earnings ranged from $6.19 to $8.69 per hour and were comprised of (a) $1.50 for every session completed, (b) $.03 for every correct answer during the sessions, and (c) a $5.00 bonus at the time of debriefing. Subjects received receipts showing daily and cumulative earnings at the end of each session. Payment was made at the end of their participation.

Apparatus

The sessions were conducted in a small room containing a table, chair and an IBM-compatible personal computer. A custom-written program displayed stimuli, arranged contingencies, and collected data. The stimuli consisted of nine arbitrary geometric figures drawn in white on a black background presented within a 120 x 120 pixel frame.

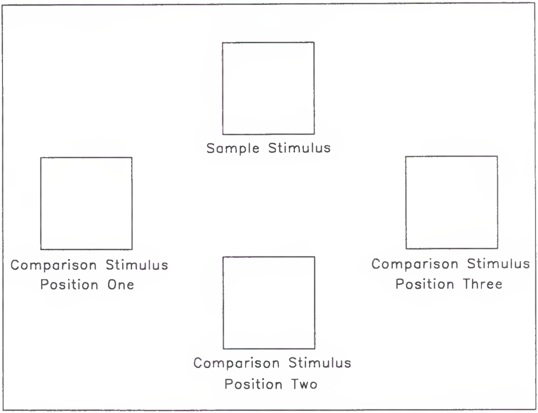

Sample Stimulus
Comparison Stimulus Position One
Comparison Stimulus Position Two
Comparison Stimulus Position Three

Figure 2. A schematic representation of the placement of stimuli during conditional discrimination trials.

Session and Trial Structure

Figure 2 shows the physical arrangement of stimuli during the condtional discrimination trials. A trial started with the presentation of a stimulus in the horizontal center of the top one-third of the monitor (hereafter, the sample). One press of the up-arrow key in the presence of the sample produced an array of three stimuli (hereafter, the comparisons) arranged in a shallow "V" in the bottom two-thirds of the monitor (see Figure 2). A response on one of the three remaining arrow keys highlighted the corresponding comparison stimulus. One press on the Enter key selected the highlighted comparison stimulus and either initiated reinforcement or an inter-trial interval (ITI). Reinforcement consisted of a 2.8-s flash of a screen showing "+ $0.03" followed by a 3-s ITI during which the screen was dark. On trials without reinforcement, the ITI began immediately following comparison choice and lasted 5.8 s. Each session consisted of 270 conditional discrimination trials, organized as 15 presentations of blocks of 18 trials. Six of the trials within a block were training trials, designed to teach the requisite conditional discriminations (given A1 select B1, not B2 or B3 (hereafter, designated by A1:B1), A2:B2, A3:B3, B1:C1, B2:C2, B3:C3) and 12 were test trials designed to test for the emergence of untrained conditional discriminations. The presentation of trial types was completely randomized within a block of 18 trials. Trials were selected from the list of 18 trial types without replacement.

Establishing the Requisite Conditional Discriminations

The six trained conditional discriminations were established using a delayed-prompting procedure (cf. Touchette, 1971). The trials began with the onset of the sample stimulus as described above. One response on the up-arrow key produced the array of comparison stimuli. On each training-trial type, the border around the experimenter-designated correct comparison stimulus turned blue, given no response, after a short delay following the onset of the comparison array. Selection of the blue-bordered comparison stimulus produced reinforcement and delayed the onset of the blue border for the next trial of that type by 500 ms. Selection of one of the other stimuli simply produced the ITI and decreased the delay to the prompt on the next presentation of that trial type by 500 ms. The delay to the prompt on the first presentation of each training trial was set at 100 ms. After that, the delays to the prompts changed in relation to the subject's response as described above, with the exception that the minimum delay was 0 s. There was no correction procedure programmed. Selection of the the experimenter-designated correct comparison stimulus was initially reinforced on every trial. For 5 of the 6 subjects, the reinforcement density was reduced to 50% following acquisition of the requisite conditional discriminations by omitting the reinforcement screen on a randomly-selected half of the training trials.

When accuracy on the trained conditional discriminations was greater than 90% for two consecutive sessions, the contingencies for two of the six training conditional relations were reversed such that selection of B2 was reinforced given A1 and selection of B1 was reinforced given A2 (A1:B2 and A2:B1). All other contingencies and features of the training remained unchanged. The delay to the prompt was not reset at the time of contingency reversal. Figure 3 shows the trained and tested conditional discriminations with the original and reversed configurations.

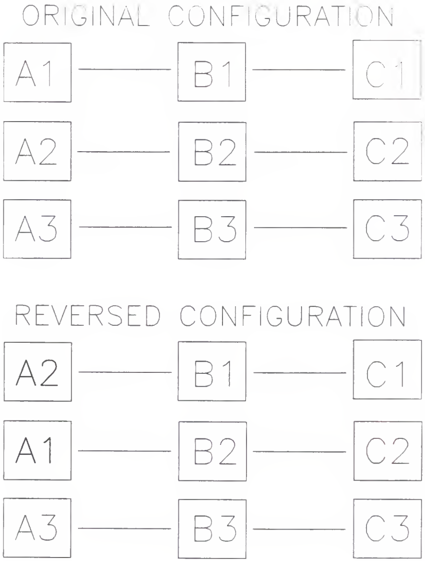


Figure 3. Trained conditional discriminations under the original (top) and reversed (bottom) contingencies. Note the reversed positions of A1 and A2 in the reversed configuration.

Testing for Emergent Conditional Discriminations

The twelve conditional discriminations used to test for the emergent properties of equivalence relations among the stimuli were presented along with the six training conditional discrimination trials from the beginning of the experiment. Choices on the test trials were never reinforced--selection of comparison stimuli simply removed all stimuli from the screen and inititated the ITI.

Instructions

Prior to the first session, each participant read an information sheet describing the attendance and payment requirements. Three participants (Subject 3, Subject 5 and Subject 10) were told only that the task involved responding to the pictures that would appear on the screen and which keys on the keyboard were active. No additional information was given. Questions were answered either by repeating this information or by saying that no more questions could be answered until the end of the experiment. The other three participants (Subject 9, Subject 12 and Subject 13) received exactly the same instructions with the sentence "There is a correct answer on every trial" added at the end of the instructions. (A copy of the instructions is included in the appendix.)

Results

The following terminological conventions will be observed throughout this section. The conditional discriminations explicitly trained via reinforcement (A:B and B:C) will hereafter be referred to as "original relations." Individual test-trial types will be described in terms of the properties they putatively assay. For example, a trial with B1 serving as the sample and A1, A2, and A3 serving as comparisons will be called a "symmetry trial" and the selection of A1 in the presence of B1 will be

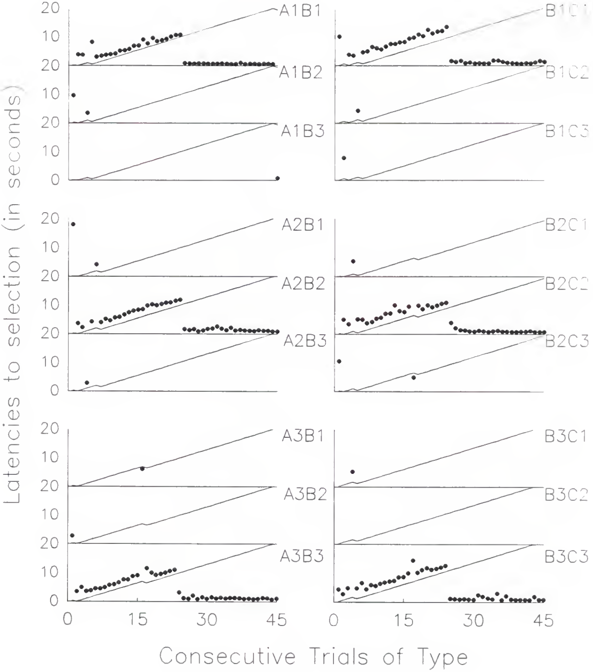


Figure 4. Distribution of choices on six trained conditional discrimination trials. The solid line shows the delay to the prompt and the dots show latency to response.

referred to as being consistent with symmetry or "symmetry-consistent." Choice of experimenter-designated correct comparison stimuli on all novel conditional discrimination trials that define the equivalence relation will be referred to as being consistent with equivalence-class formation or "equivalence-consistent."

Performance on the Training Conditional Discrimination Trials

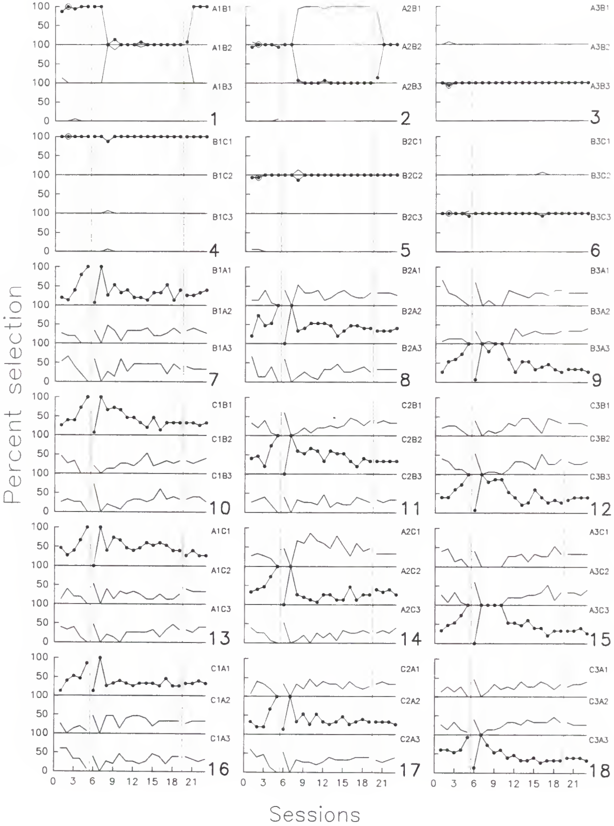
Figure 4 shows acquisition data for the six original relations for Subject 3. The groups of graphs (hereafter, clusters) in the left and right hand columns show data from the A-B and B-C trial types, respectively. Each cluster contains three graphs relating to each of the three comparison choices available. For example, the cluster on the top left shows data from the A1:B1 conditional discrimination. The filled circles in the top graph (within the cluster) shows latencies to select B1 given A1 as the sample. The solid line shows the delay to the onset of the prompt. The filled circles in the middle and bottom graphs within the cluster show latencies to selection of B2 and B3, respectively, given A1 as the sample. These graphs simultaneously show which comparison stimulus was selected and the latency to that choice for every trial. The data presented are representative of all six subjects' performances on the training trials.

For each subject, acquisition of the requisite conditional discriminations occurred in two distinct stages. The first stage was characterized by the development of control by the compound stimulus, consisting of the experimenter-designated correct comparison stimulus and the prompt. Comparison choices on the first few trials were unrelated to either the prompt or the particular sample stimulus simultaneously displayed. By the end of the first session, however, the comparison stimuli with the added prompt were chosen exclusively. The second stage involved the development of conditional control over comparison choices by the presence of particular sample stimuli. This stage was characterized by the selection of the experimenter-designated comparison stimulus in the presence of particular sample stimuli prior to the onset of the prompt. This point will hereafter be referred to as the moment of original relations acquisition. All subjects acquired the original relations within four sessions.

Performance on the Derived Conditional Discrimination Trials

Figures 5 through 10 show data on the percent of correct trials per session for each of 18 different trial types for six subjects. For each individual trial type (e.g., A1:B1), the figure presents a group of three graphs (hereafter, cluster) displaying the proportion of trials (per session) on which each, of three available comparisons, were selected. Each cluster has been numbered to allow easier referencing of figures during description of the results. In Figures 5 through 10, Clusters 1 through 6 present data on the original relations and Clusters 7 through 12, 13 through 15, and 16 through 18 present data on symmetrical, transitive and symmetrically-transitive trial types, respectively. In each cluster, the filled circles represent percent of trials on which the experimenter-designated correct comparison stimulus was selected. (The filled circles always represent selection of the stimulus designated "correct" during the original contingencies.) The remaining two graphs in each cluster show percent of trials on which either of the other comparison stimuli available were selected. Each column presents data for one of the three putative stimulus equivalence classes. That is, each of the three columns (from left to right) presents data for the six conditional discriminations embodied in the A1-B1-C1, A2-B2-C2, and A3-B3-C3 classes, respectively. The vertical lines within

Figure 5. Data are presented for 18 conditional discrimination trials that trained and tested for the emergence of three, 3-member equivalence classes. Clusters 1-6 present data for the trained conditional discriminations. Clusters 7-12 present data for the related symmetry trials. Clusters 13-15 and 16-18 present data for the transitivity and symmetrical-transitivity trial types, respectively. For Subject 3, the vertical lines separate data from baseline, contingency-reversal, and a return to baseline phase. See text for details.


Percent selection
Sessions
100
50
0
A1B1
A1B2
A1B3
1
A2B1
A2B2
A2B3
2
A3B1
A3B2
A3B3
3
B1C1
B1C2
B1C3
4
B2C1
B2C2
B2C3
5
B3C1
B3C2
B3C3
6
B1A1
B1A2
B1A3
7
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B2A2
B2A3
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C2B1
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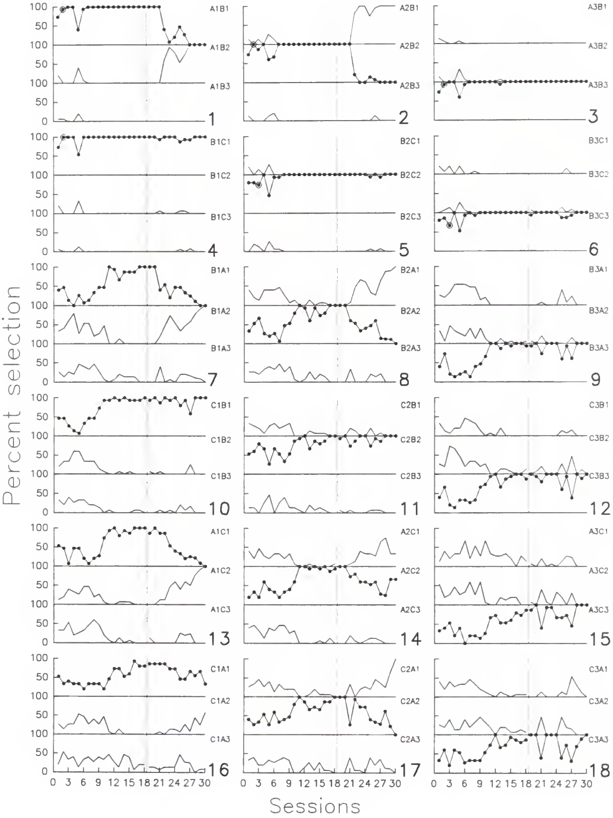
A3C3
15
C1A1
C1A2
C1A3
16
C2A1
C2A2
C2A3
17
C3A1
C3A2
C3A3
18
0
3
6
9
12
15
18
21

Figure 6. Data are presented for 18 conditional discrimination trials that trained and tested for the emergence of three, 3-member equivalence classes. Clusters 1-6 present data for the trained conditional discriminations. Clusters 7-12 present data for the related symmetry trials. Clusters 13-15 and 16-18 present data for the transitivity and symmetrical-transitivity trial types, respectively. For Subject 5, the vertical lines separate data from the baseline and contingency-reversal phases. See text for details.


Percent selection
Sessions
100
50
0
0 3 6 9 12 15 18 21 24 27 30
A1B1
A1B2
A1B3
1
A2B1
A2B2
A2B3
2
A3B1
A3B2
A3B3
3
B1C1
B1C2
B1C3
4
B2C1
B2C2
B2C3
5
B3C1
B3C2
B3C3
6
B1A1
B1A2
B1A3
7
B2A1
B2A2
B2A3
8
B3A1
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13
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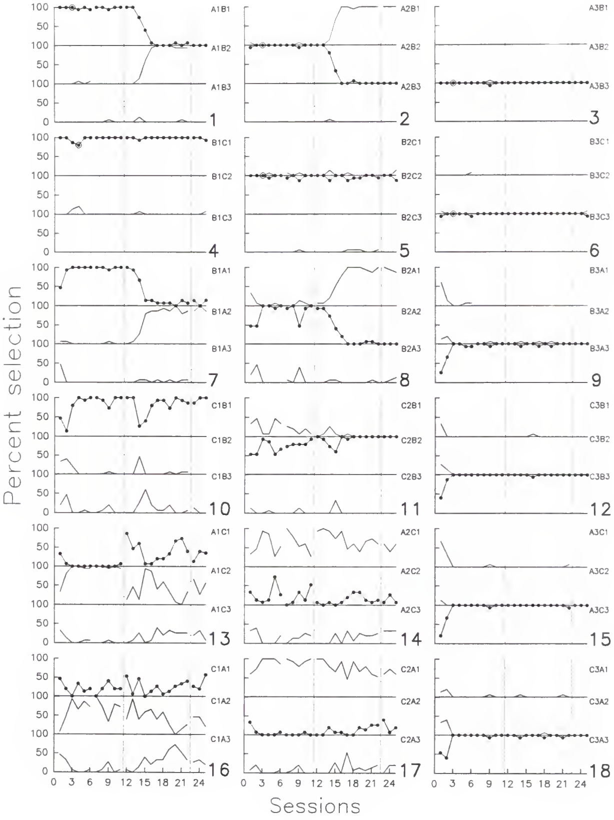
A2C3
14
A3C1
A3C2
A3C3
15
C1A1
C1A2
C1A3
16
C2A1
C2A2
C2A3
17
C3A1
C3A2
C3A3
18

Figure 7. Data are presented for 18 conditional discrimination trials that trained and tested for the emergence of three, 3-member equivalence classes. Clusters 1-6 present data for the trained conditional discriminations. Clusters 7-12 present data for the related symmetry trials. Clusters 13-15 and 16-18 present data for the transitivity and symmetrical-transitivity trial types, respectively. For Subject 10, the vertical lines separate data from baseline, contingency-reversal and a phase during which instructions were delivered. See text for details.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24

each plot separate different experimental conditions. In Clusters 1 through 6, open circles around the filled symbols mark the session during which the original relations were acquired.

Figures 5, 6, and 7 show data for participants (Subjects 3, 5, and 10) who received minimal instructions at the start of the experiment. Subject 3 and 5's choices became equivalence-consistent by Sessions 5 and 18, respectively (see Figures 5 & 6, Clusters 7 through 18). For both subjects, there was a lag between the acquisition of the original relations and the emergence of equivalence-consistent choices--three sessions for Subject 3 and nine sessions for Subject 5. Subject 10's choices on symmetry trials were accurate by Session 4 but remained inaccurate on two of three transitivity trials and two of three symmetrical-transitivity trials throughout the experiment. In addition, Subject 10's performance on the symmetry trials was accurate prior to the acquisition of the original relations as defined here--even while he continued to wait for the prompt on the training trials. With respect to the errors on two of the three transitivity trial types, Cluster 13 on Figure 6 shows that Subject 10's inaccurate performance on A1-C1 trial types was due to the exclusive selection of C2 given A1. Cluster 17 on Figure 6 shows that the subject's inaccurate performance on C2-A2 trial types was due to the exclusive selection of A1 given C2. Thus, the sample and comparison functions of A1 and C2 (the stimuli involved in the A1:C1 and C2:A2 trials) were interchangeable even though they were inconsistent with the trained original relations as well as the derived symmetry relation.

The reversal of contingencies for the A1:B1 and A2:B2 original relations produced similar effects for all three subjects on the trained trial types but different effects on the derived trial types. Following the change in contingencies, each of the three subjects continued to select B1 given A1 and B2 given A2 for a few sessions despite a substantial decrease in the amount of money earned per session. The "incorrect" comparison choices on the training trials with the reversed contingencies served to decrease the delay to the prompt on each trial such that each subject reencountered the prompt within two-three sessions after the reversal of contingencies. Prior to contact with the prompt, Subject 5 and 10's performances on derived trial types remained consistent with performance on the original relations trials.

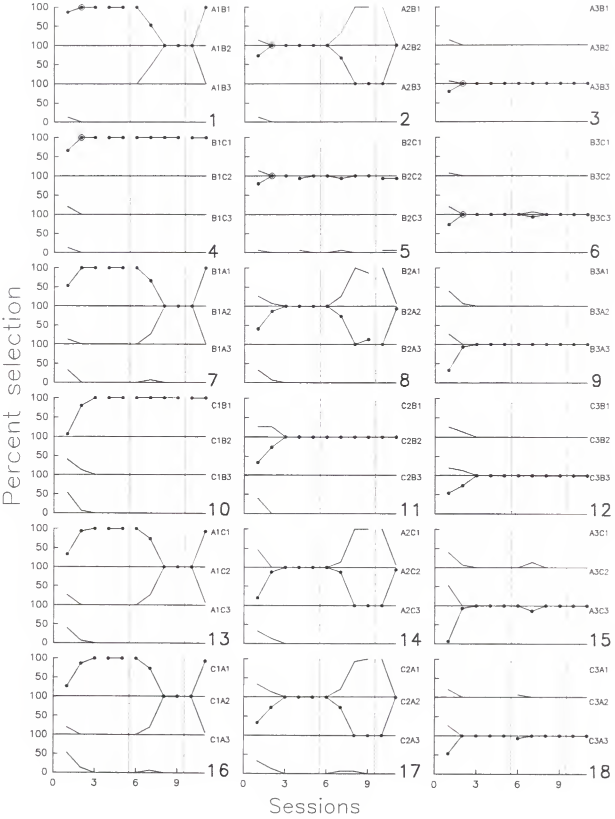
For Subject 3, however, the first session of reversed contingencies produced a dramatic change in performance on all derived trial types. After the first block of trials, this subject's performance was characterized by an explicit rejection of the equivalence-consistent comparisons on all 12 derived trial types. He began selecting the other available comparisons about equally often even while his performance on the original relations trials remained consistently "accurate" with respect to the pre reversal contingencies. During the second post reversal session, his performance on all 12 derived trial types was again equivalence-consistent with pre reversal contingencies on the original relations. Beginning with the third session, Subject 3's choices on the original relations trials became abruptly realigned with the reversed contingencies and stayed in accord for the remainder of the condition. His performance on the derived trial types, however, slowly deteriorated across the remainder of the condition. A return to baseline contingencies for the two original relations produced an abrupt change in his comparison choices on those trial types after one session. His accuracy on the derived trial types, however, remained at chance levels.

Subject 5 and 10's performances following contingency reversal were similar to each other on all derived symmetry trials, but different on the transitivity and symmetrical-transitivity trials. Each subject's performance on symmetry trials reversed in accord with the changed contingencies on the original relations trials. For Subject 5, the change in symmetry-trial performance preceded the change in performance on original relations trials by one session. For Subject 10, the change in symmetry-trial performance was coincident with changes in the performance on the original relations trials. For both subjects, performance on all C:B symmetry trials and on B3:A3 symmetry trials was essentially unchanged. Subject 5's performance on transitivity and symmetrical-transitivity trials showed a trend toward realignment late in the condition. Subject 10's performance on A1:C1 and C1:A1 trials remained variable while accuracy on A2:C2 and C2:A2 trials decreased. The addition of the instruction "There is a correct answer on every trial" produced no change in Subject 10's choices.

In sum, 2 of the 3 subjects' comparison selections on derived trial types became consistent with equivalence relations after the original relations were acquired. The third subject's performance on transitivity and symmetrical-transitivity trials was inconsistent with equivalence relations, but showed reversibility of sample and comparison functions nonetheless. The reversal of contingencies affected performance on original relations trials similarly for all subjects. The effect of the reversal on symmetry trial types was similar for 2 of 3 subjects, but different on the transitivity and symmetrical-transitivity trial types.

Figures 8, 9, and 10 show data for Subjects 9 , 12, and 13, respectively,

Figure 8. Data are presented for 18 conditional discrimination trials that trained and tested for the emergence of three, 3-member equivalence classes. Clusters 1-6 present data for the trained conditional discriminations. Clusters 7-12 present data for the related symmetry trials. Clusters 13-15 and 16-18 present data for the transitivity and symmetrical-transitivity trial types, respectively. For Subject 9, the vertical lines separate data from baseline, contingency-reversal and a return to baseline. See text for details.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Sessions

Figure 9. Data are presented for 18 conditional discrimination trials that trained and tested for the emergence of three, 3-member equivalence classes. Clusters 1-6 present data for the trained conditional discriminations. Clusters 7-12 present data for the related symmetry trials. Clusters 13-15 and 16-18 present data for the transitivity and symmetrical-transitivity trial types, respectively. For Subject 12, the vertical lines separate data from the baseline and contingency-reversal phases. See text for details.

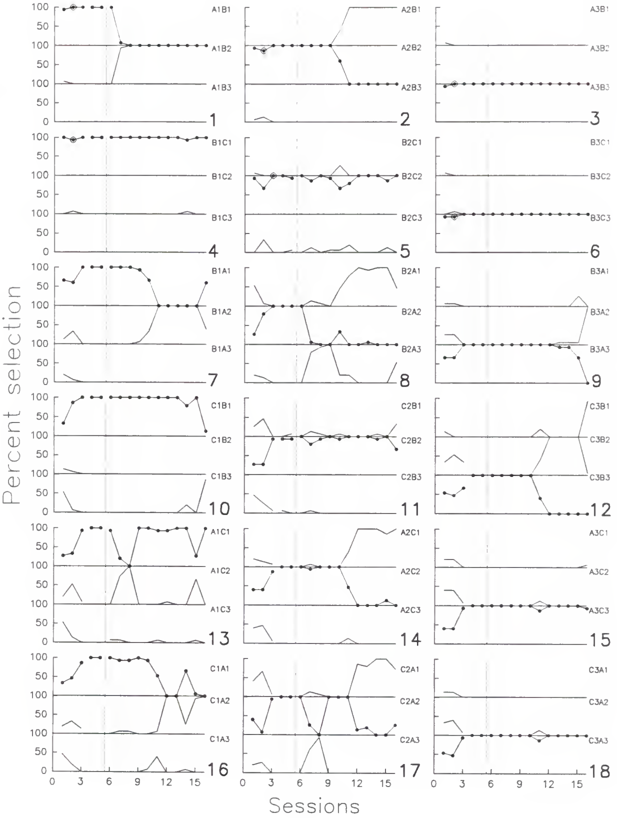
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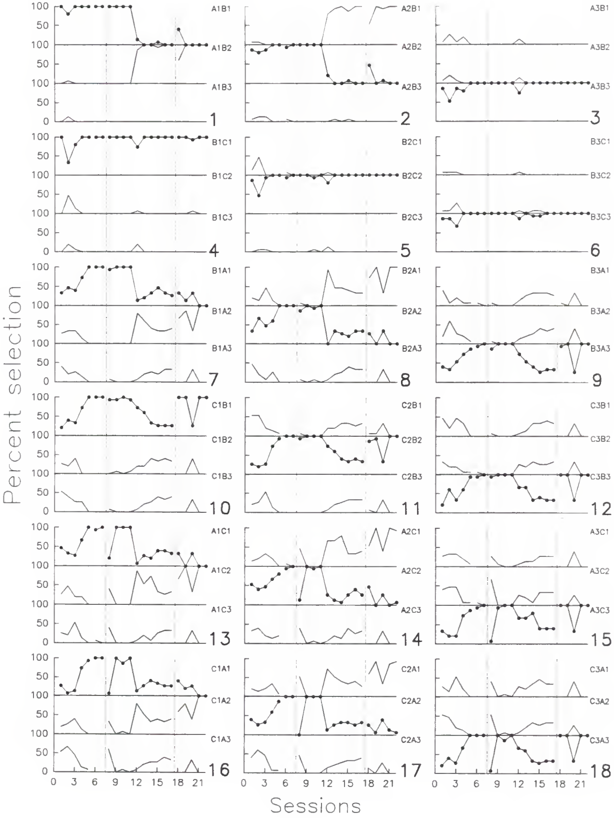
Figure 10. Data are presented for 18 conditional discrimination trials that trained and tested for the emergence of three, 3-member equivalence classes. Clusters 1-6 present data for the trained conditional discriminations. Clusters 7-12 present data for the related symmetry trials. Clusters 13-15 and 16-18 present data for the transitivity and symmetrical-transitivity trial types, respectively. For Subject 13, the vertical lines separate data from baseline, contingency-reversal and a phase during which instructions were delivered. See text for details.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who received additional instructions specifying that there was a correct answer on every trial. These figures show that conditional discrimination performance became equivalence-consistent by Session 2 for Subject 9, Session 3 for Subject 12 and Session 5 for Subject 13. For 2 of the 3 subjects (12 and 13), there was a lag of one session between acquisition of the original relations and the emergence of equivalence relations. For Subject 9, equivalence-consistent responding began during the same session the original relations were acquired. There was no difference in the lag between the acquisition of original relations and systematic responding on the different trial types for any subject.

As before, the reversal of contingencies produced qualitatively similar effects for all 3 subjects on the training trial types, but different effects on the test trials. Each subject, for example, persisted in his/her selection of B1 given A1 and B2 given A2 despite decreases in amount of money earned. Subject 9 persisted for one session and Subject 13 for four sessions. Subject 12's selections became aligned with the new contingencies after one session for the A1:B1 trial type, but after four sessions for the A2:B2 trial type. During these four sessions, there was a change on the related symmetry trial (B2:A2), but it involved selection of A3 given B2, not A1. During the fifth and sixth sessions following reversal, Subject 12's responses on B1:A1 (symmetry) and C1:A1 (symmetrical-transitivity) trials, respectively, became realigned with the reversed contingency although performances on C1:B1 (symmetry) and A1:C1 (transitivity) remained consistent with pre reversal patterns. Also beginning with the sixth session following reversal, Subject 12's performance on B2:A2 (symmetry), A2:C2 (transitivity) and C2:A2 (symmetrical transitivity) became realigned in accord with the reversed contingency. Her performance on

B3:A3 and C3:B3 (symmetry) trials was disrupted during these sessions.

For Subject 13 there was a lag of four sessions after which his performance on all of the conditional discriminations embodied in the A1-B1-C1 and A2-B2-C2 classes became realigned with the new contingencies for one session. After this, Subject 13's accuracy on all derived conditional discriminations decreased to approximately chance levels. After 10 sessions in this condition, the subject was reminded that there was always a "correct" answer on every problem. His accuracy on all of the derived trial types immediately improved and was near 100% accurate by the fifth session. Subject 9's performance differed in that the conditional discriminations embodied in the A3-B3-C3 class were not disrupted. The reversal in original relations contingencies served to realign all related conditional discriminations. A return to the baseline contingencies produced an immediate reversal of all related derived trial types.

In sum, the effect of the contingency reversal on original relations' performance was qualitatively similar for all subjects but dissimilar on the derived trial types. For five of the six subjects (except Subject 3), responding on symmetry trial types became realigned with the changed original relations. For all 5 subjects, the initial changes in the derived symmetry trials were limited to the particular original relations participating in the contingency reversal (i.e., the effect did not extend to all symmetrical relations). The exception was a disruption in Subject 12's performance on C3:B3 trials. Three of the subjects' (5, 12, and 13) performances on transitivity trials showed partial realignment with the newly imposed contingencies. Subject 12's performance showed realignment of the A2:C2 trials but not the A1:C1 trials and Subject 13 showed the effect only for one session.

With respect to the symmetrical transitivity trial types, Subject 9 and 12 showed nearly complete realignment. Subject 10's performance appeared to be consistent with the reversed contingencies, but was actually a continuation of pre reversal patterns of choices.

Discussion

These data show that all 6 subjects acquired the original relations within a few sessions. For all subjects, acquisition of the original relations was characterized by a two-stage process: (a) the acquisition of discriminative control over selections by the prompted stimulus compound and (b) the development of conditional control by the sample stimulus. Five of the six subjects also began engaging in conditional discriminations consistent with equivalence-class formation a few sessions after acquisition of the original relations. The exception was Subject 10 (minimal instructions). His performance was inaccurate on the transitivity and symmetrical-transitivity trials, but accurate on the symmetry trials. On the whole, these data show that the deviations from more standard preparations introduced into the current procedure did not hinder the development of equivalence classes. As such, the procedure appears to be a viable means of training requisite conditional discriminations and testing for the emergence of novel conditional discriminations indicative of equivalence relations among the stimuli.

A benefit was the ability to relate the acquisition of the original relations to the emergence of equivalence relations among the stimuli. These data show that systematic and accurate responding on derived conditional discrimination trials depended upon the acquisition of the original relations. Five of the 6 subjects' performances became consistent with equivalence class formation only after the original relations were acquired. For all subjects, comparison choices on derived trial types were about equally distributed prior to the acquisition of the original relations. Thus, responding also became "systematic" only after original relations acquisition. Because the explicitly trained original relations establish the defining properties of obtained conditional discriminations, there is a sense in which equivalence classes cannot be seen prior to the acquisition of the original relations. It might, however, be possible to observe consistent responding on derived trial types prior to the acquisition of original relations. These data suggest that acquisition of the original relations produced two changes in the subjects' performances on derived trial types: (a) it constrained the allocation of responding on the derived trial types to just one stimulus, and (b) for 5 of the 6 subjects, it produced conditional discrimination performances consistent with the formation of equivalence classes.

For 5 of the 6 subjects (with the exception of Subject 9), there was a lag between the acquisition of the original relations and the emergence of conditional discriminations consistent with the properties of equivalence relations. This finding is also consistent with the delayed emergence of equivalence-consistent responding seen in previous research (Fields, Adams, Verhave, & Newman, 1990; Lazar, Davis-Lang, & Sanchez, 1984; Sidman, Kirk, & Willson-Morris, 1985; Spradlin, et al., 1973). There have been several accounts offered for this delayed emergence (Saunders & Green, 1992; Sidman, 1992). Sidman et al., (1985) for example, suggested that the delayed emergence of equivalence relations may be due to the contextual control exerted by the test trials themselves. Specifically, they suggest that "[t]eaching the baseline relations may only create the potential for class formation, a potential that remains unrealized until the test itself (Sidman et al., 1985, p. 39)." The data presented here are important in this context because they show the delayed emergence of equivalence-consistent responding even with contextual cues associated with the testing trials available from the beginning of the experiment. Perhaps extended exposure to reinforced trials is necessary for the emergent reversibility of stimulus functions required for accurate performance on the testing trial types. Or perhaps responding consistently on a few interrelated conditional discriminations is necessary and sufficient for the emergent interchangeability of stimulus functions (see Saunders, et al., 1988; Harrison & Green, 1990). Although the current data do not resolve this issue, the procedures could be readily modified to investigate this possibility directly.

The data from the contingency reversal manipulations show that the various stimulus-control relations required to document the existence of equivalence classes reacted differently to changes in the original relations. For all subjects, responding on symmetry trials changed in accord with changes in the original relations. These data are generally consistent with previously reported effects of contingency reversal manipulations (Pilgrim & Galizio, 1990, 1995; Pilgrim, Chambers, & Galizio, 1995; see Pilgrim & Galizio, 1997 for a summary). Response patterns on the transitivity and symmetrical-transitivity trial types, however, were varied and not consistent with the patterns reported by Pilgrim and Galizio. Two of the 6 subjects in the current study showed complete reorganization of the testing conditional discriminations such that the performance was consistent with equivalence classes predicted by the changed original relations. The other 4 subjects' selections failed to show evidence of re-organized equivalence classes despite the fact that responses on the symmetry trials had become consistent with the changed original relations. These findings raise questions about the view that stimulus-equivalence is wea fundamental or integrated process (Sidman, 1990; 1994). Rather, these data suggest that performances on derived trial types can become independent of the original relations on which they are putatively based. These data also support Pilgrim and Galizio's (1995) warning about exercising caution in concluding the existence of equivalence relations based on the results of tests of just a few properties (cf. Sidman, 1986).

In summary, these data suggest that the procedural modifications introduced did not hinder the development of equivalence classes. As such, the procedure represents a viable means of investigating the development and modification of equivalence relations among stimuli in a more dynamic manner than has been possible before. These findings have also called into question existing interpretations of the delayed emergence of equivalence relations among stimuli. In addition, the findings from the reversal phase add generality to the effects of contingency reversal manipulations previously reported. Finally, the data raise some questions about the equivalence relation as a fundamental and integrated behavioral process.

EXPERIMENT 2

The extension of stimulus functions via equivalence classes has been documented many times. Taken together, these and other studies show that respondent eliciting (e.g., Dougher et al., 1994) and operant discriminative (e.g., Barnes & Keenan, 1993; Wulfert & Hayes, 1988) and consequential functions (Hayes, et al., 1991) imparted to one member of an equivalence class will extend to other member stimuli in the absence of direct contingencies supporting such extensions. Several features of the conventional procedures, however, do not permit an unequivocal account of the role of equivalence relations in the extension of stimulus functions. The precise nature of the dependencies between the two phenomena, therefore, remains to be understood.

A problem with conventional procedures is the number of comparison stimuli used in a conditional discrimination trial. As Sidman (1987) has pointed out, the use of two comparison stimuli does not alllow one to distinguish between a response that selects a stimulus and a response that simply avoids the other alternative. Notice, for example, that if a subject is taught to pick B1 and not B2 in the presence of A1, then subsequent selection of B2 and not B1 in the presence of A2 can be either selection of B2 or the rejection of B1, given the earlier history. The same point can be made with respect to extension-of-function research that uses only two response patterns. In other words, given instructions or a history of responding with two distinct topographies (say, high vs. low rate), the occurrence of a particular pattern of behavior in the presence of a novel stimulus could be either under control of actual extension of function or it could be an instance of "not" responding in the first way. Several of the studies cited above used only two choices in the conditional discrimination trials and made only two patterns available in the transfer of function tests (Barnes & Keenan, 1993; Catania et al., 1989; Gatch & Osborne, 1989; Hayes, et al., 1991; and Lazar, 1977). The problems inherent in the use of only two choices in a conditional discrimination task are similar to the problems encountered when only two patterns of behavior are used to test for extension of stimulus functions (see Barnes & Keenan, 1993, for an example).

This problem is further compounded by the use of explicit instructions regarding the nature of the task. Most of the experiments cited above gave subjects detailed instructions regarding the nature of the task. For example, subjects have been told that they were expected to find which one of the stimuli went with the one on top (the sample), that sometimes the stimuli would show up and they would be expected to deal with them in a different way, and that paying attention to the first task would help them figure out what to do in the second task. The use of explicit instructions regarding the nature of the task makes it difficult to evaluate exactly how equivalence class formation may have been involved. For example, the instructions may predispose the subject to look for similarities between the two different types of tasks. This predisposition, combined with the availability of only two choices, may equivalence-consistent performance and extension of function to occur for reasons other than the formation of equivalence relations and the extensions of stimulus function.

Finally, existing procedures fail to provide unequivocal evidence implicating the mediating role of equivalence classes. In the study by Catania et al. (1989) described earlier, for example, a subject was taught to respond at a high or low rate under a multiple schedule with two stimuli (A1 and A2) serving as component-correlated cues. These stimuli were then used as comparisons in conditional discrimination tasks with novel stimuli (B1 and B2) serving as samples. The subject was taught to pick B1 given A1 as a sample and B2 given A2 as a sample. Subsequent exposure to the multiple schedule arrangement showed that the novel stimuli were effective as component-correlated stimuli. In other words, the discriminative properties of A1 and A2 had been extended to B1 and B2, respectively. This extension of stimulus function, however, was seen prior to the demonstration that the stimuli had become interchangeable in the context of a conditional discrimination procedure--a requirement for positing the existence of equivalence relations among stimuli. Subsequent conditional discrimination probes did show that the novel stimuli were also effective as comparisons in the conditional discrimination procedure (symmetrical property) and these data were used to suggest that the original training had established equivalence relations among the stimuli, which then mediated the extension of function. It could also be argued, however, that the relation of conditionality (not equivalence) between the sample and comparison, established during the original conditional-discrimination training, was sufficient for the extension of stimulus function independent of any equivalence relations among the stimuli.

The train-and-test feature, common in procedures of this sort, does not permit an unequivocal demonstration of extension of stimulus function via equivalence-class formation. What is needed is a procedure by which the development of equivalence classes and the extension of stimulus functions can be tracked together over time. To that end, this experiment trained the original relations, tested for the emergence of equivalence relations, established the original discriminative functions, and tested for the extensions of those functions via interlaced trials from the beginning of the experiment.

Method

Subjects

Two males and one female were recruited via advertisements placed in the campus newspaper and were selected on the basis of availability and lack of familiarity with behavior analysis. One of the male subjects was a 38 year old employee of the University of Florida. The other two participants were undergraduate students. The durations of the subjects' participation ranged from 12 to 15 sessions and the amount of earnings ranged from $5.25 to $7.96 per hour.

Apparatus

The setting and apparatus were identical to that described in Experiment 1.

Session and Trial Structure

Each session consisted of two distinct segments. In the first segment (hereafter, the equivalence segment), original relations were trained and equivalence relations were tested in the manner described in Experiment 1. In the second segment (hereafter, the discrimination segment) discriminative functions were established for one stimulus from each of three putative equivalence classes and the extension of those functions to the other members of the class was tested. A block of trials during the discrimination segment was comprised of nine trials--one presentation of each of the nine stimuli. Three of these stimuli (A1, A2, and A3) were each made discriminative for a different response pattern via reinforcement. The remaining six stimuli (B1, C1, B2, C2, B3, C3) defined the probe trials on which the extension of stimulus functions were tested in the absence of reinforcement. Each session started with a block of 18 equivalence trials. When these trials had been completed, the program displayed the message "Press any key to continue" on the screen and waited for the subject to initiate the discrimination segment. Sessions consisted of 15 alternations of blocks of trials from the equivalence and discrimination segments.

Establishing the Requisite Conditional Discriminations

The original relations were trained in a manner identical to Experiment 1. When accuracy was greater than 90% on all conditional discrimination trial types for one session, the contingencies for two of the original relations were reversed such that selections of B1 and B2 were reinforced given A2 and A1 as samples, respectively.

Testing for Emergent Conditional Discriminations

The 12 conditional discrimination trials that test for the emergent properties of equivalence relations among the stimuli were randomly presented, along with the six training conditional discrimination trials in a block of trials, as described in Experiment 1.

Establishing the simple successive discriminations

Each of three stimuli (A1, A2, and A3) were established as discriminative stimuli for one of three different response patterns. A trial began with a single stimulus displayed in the horizontal and vertical center of the screen. The response was comprised of a three-key sequence which always began with a Space Bar press and always ended with an Enter Key press, the middle response being allowed to vary in relation to the stimulus presented on the screen. (Because the first and third responses in this sequence were invariant, the sequences will hereafter be referred to in terms of the middle response only.) On all simple discrimination trials, the only keys active were the Space Bar, the (horizontally arrayed) "1," "4," and "7" number keys and the Enter key. Responses on other keys were recorded but did not end the trial or produce any visible change on the screen. In the presence of A1, for example, the sequence [Space Bar - "1" - Enter] produced reinforcement and the trial continued until the subject produced that sequence of responses. This "forced" procedure was used to limit the variability in the responses and hasten the acquisition of the simple discrimination. The reinforcement screen was identical to that used during the equivalence segment--a 2.8-s flash of a screen showing "+ $0.03." This was followed by a 3-s ITI during which the screen was dark. The contingencies in place in the presence of A1 and A2 were reversed at the same time as the reversal in the equivalence segment regardless of the obtained pattern of responses on the successive simple-discrimination trials. Following the reversal of contingencies, pressing "1" produced reinforcement in the presence of A2 as opposed to A1 and pressing "4" produced reinforcement in the presence of A1 as opposed to A2.

Testing for the Emergent Extension of Function

Each of the other six stimuli were randomly selected from a list without replacement and presented within a block of nine trials. These trials were identical to the training trials except that the consequence was a dark screen and a 5.8-s ITI.

Instructions

The subjects were told only that (a) the task involved responding to the pictures that would appear on the screen in front of them, (b) different parts of the keyboard were to be used on the two different tasks, and (c) there was a correct answer on every trial. The instructions are shown in the appendix.

Results

Data are presented for Subject 18 (Figures 11, 12, and 13), Subject 23 (Figures 14, 15, and 16), and Subject 24 (Figures 17, 18, and 19). There are 3 figures for each subject with each figure showing data from the six conditional discriminations embedded in one stimulus equivalence class and the simple discriminations for each of the three stimuli involved. In each figure, the first two rows of grouped-graphs (hereafter, clusters) show data from the conditional discrimination trials that trained and tested for the development of equivalence relations among stimuli. Each cluster has been numbered for easier referencing. Clusters 1 and 2 show data from the original relations trials, Clusters 4 and 5 show data from the related symmetry trials and Clusters 3 and 6 show data from the transitivity and symmetrical-transitivity trial types, respectively. Cluster 7 on each figure shows data from the simple discrimination training trials ("A" stimuli) with the top, middle, and bottom panels showing percent of response sequences containing a 1, 4, or 7, respectively. Clusters 8 and 9 on each figure show data from the simple discrimination probe trials in the presence of "B" and "C" stimuli. For each cluster, the filled circles represent experimenter-designated "correct" responses. (The filled circles always represent selection of the stimulus designated "correct" during the original contingencies.) For example, Figure 11 shows data from the conditional and

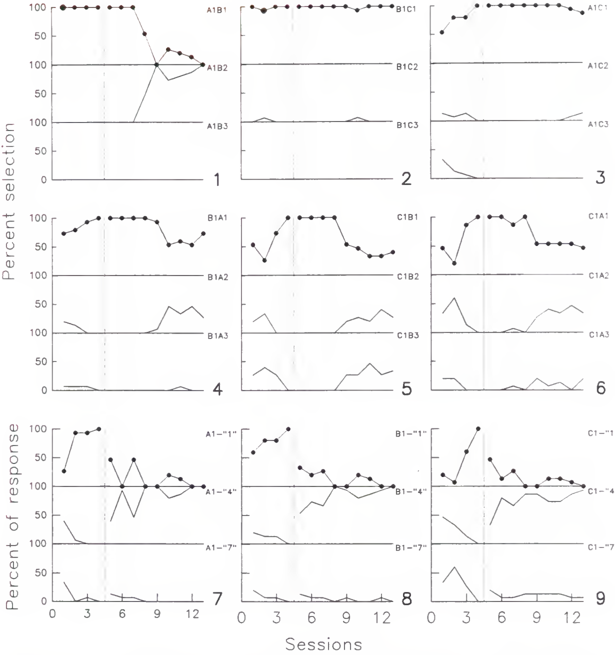

Figure 11. Data for six conditional and three simple discrimination trials for the A1–B1–C1 class of stimuli are presented for Subj. 18. Clusters 1 through 6 and 7 through 9 show data from the conditional and simple discrimination trials, respectively. The vertical lines separate data from the baseline and contingency reversal phases. See text for details.

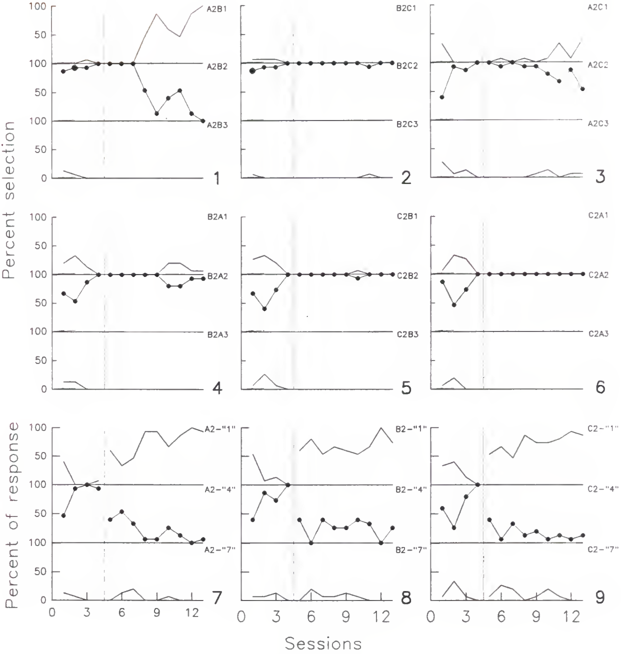

Figure 12. Data for six conditional and three simple discrimination trials for the A2–B2–C2 class of stimuli are presented for Subj. 18. Clusters 1 through 6 and 7 through 9 show data from conditional and simple discrimination trials, respectively. The vertical lines separate data from the baseline and contingency reversal phases. See text for details.

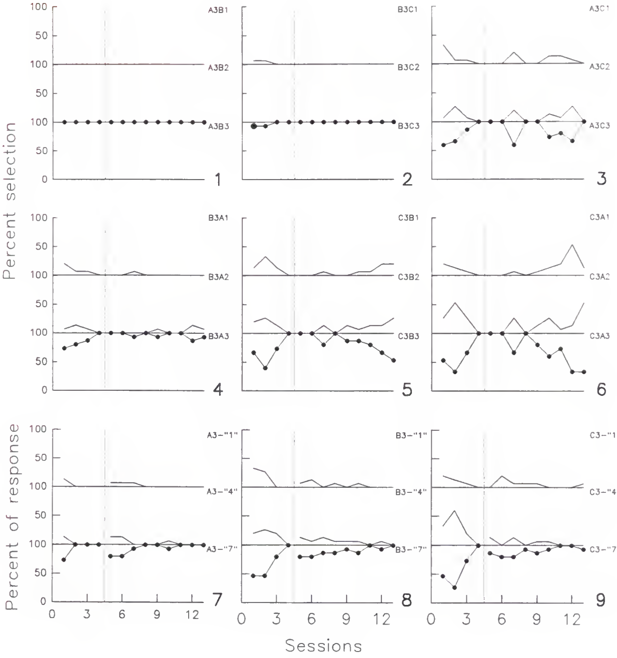

Figure 13. Data for six conditional and three simple discrimination trials for the A3—B3—C3 class of stimuli are presented for Subj. 18. Clusters 1 through 6 and 7 through 9 show data from conditional and simple discrimination trials, respectively. The vertical lines separate data from the baseline and contingency reversal phases. See text for details.

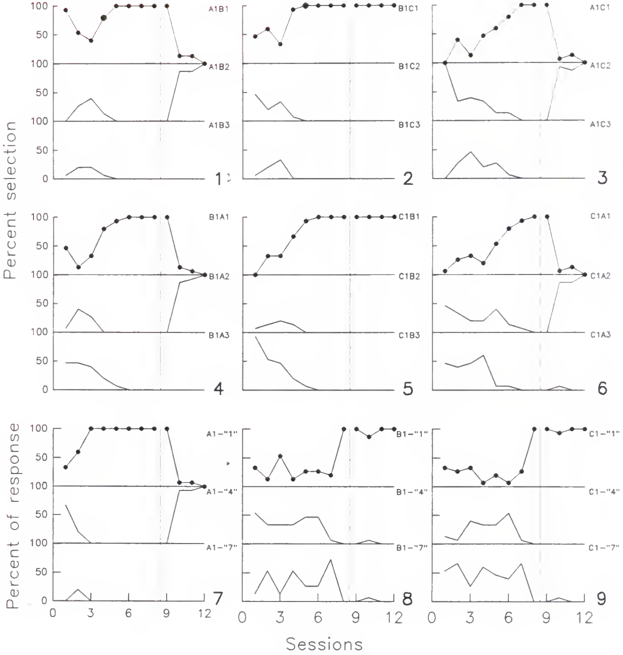

Figure 14. Data for six conditional and three simple discrimination trials for the A1—B1—C1 class of stimuli are presented for Subj. 23. Clusters 1 through 6 and 7 through 9 show data from conditional and simple discrimination trials, respectively. The vertical lines separate data from the baseline and contingency reversal phases. See text for details.

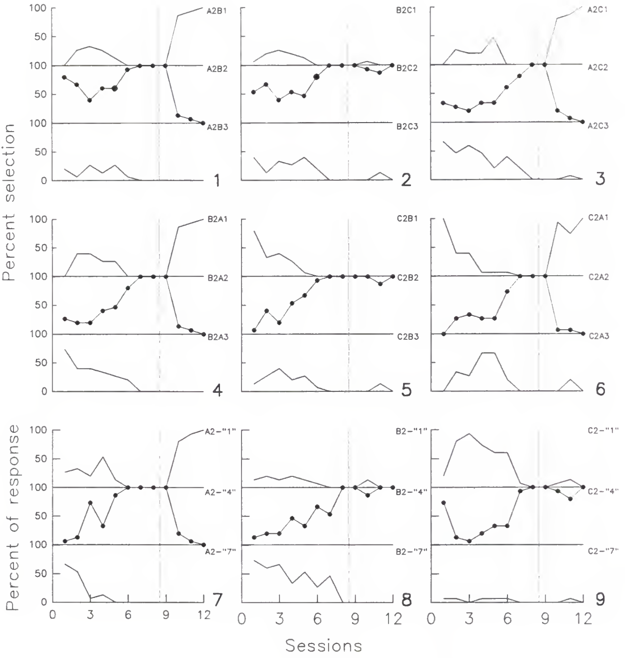

Figure 15. Data for six conditional and three simple discrimination trials for the A2–B2–C2 class of stimuli are presented for Subj. 23. Clusters 1 through 6 and 7 through 9 show data from conditional and simple discrimination trials, respectively. The vertical lines separate data from the baseline and contingency reversal phases. See text for details.

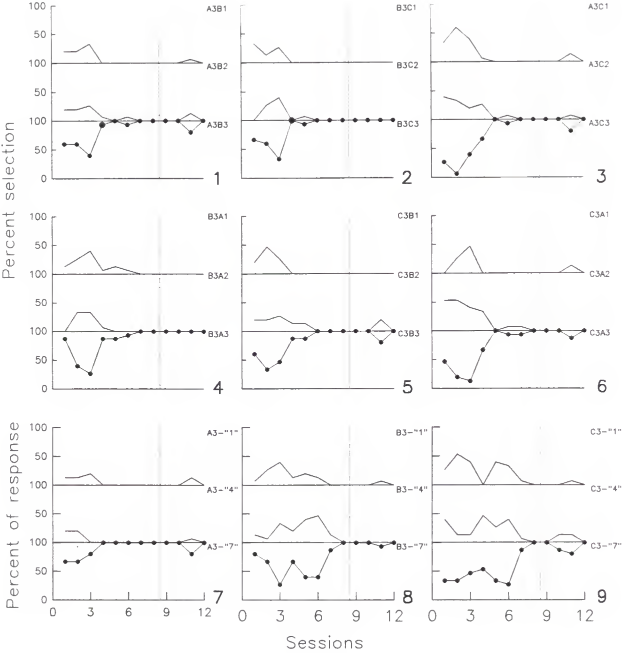

Figure 16. Data for six conditional and three simple discrimination trials for the A3–B3–C3 class of stimuli are presented for Subj. 23. Clusters 1 through 6 and 7 through 9 show data from conditional and simple discrimination trials, respectively. The vertical lines separate data from the baseline and contingency reversal phases. See text for details.

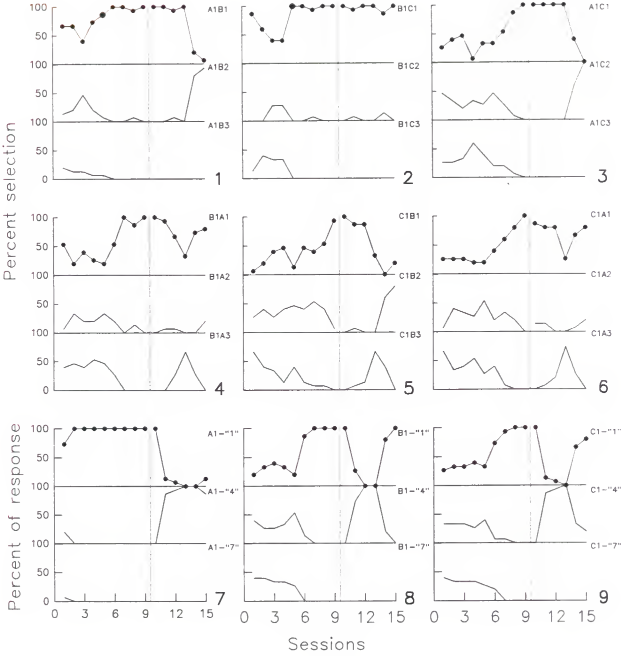

Figure 17. Data for six conditional and three simple discrimination trials for the A1–B1–C1 class of stimuli are presented for Subj. 24. Clusters 1 through 6 and 7 through 9 show data from conditional and simple discrimination trials, respectively. The vertical lines separate data from the baseline and contingency reversal phases. See text for details.

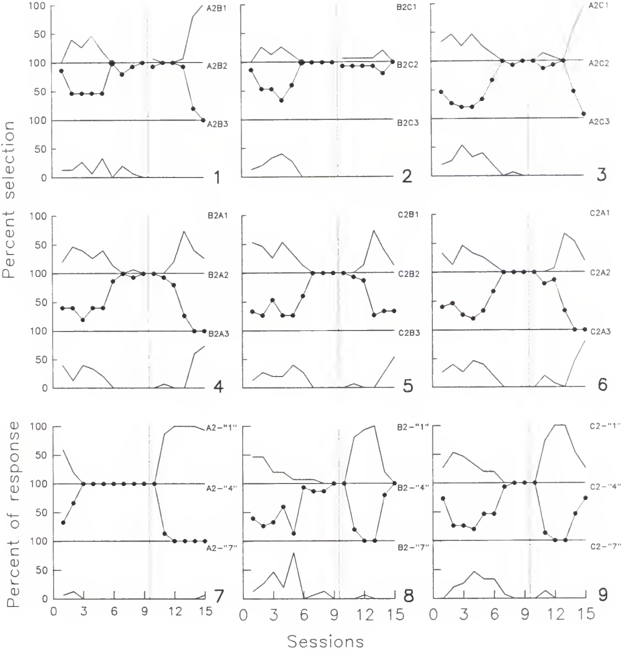

Figure 18. Data for six conditional and three simple discrimination trials for the A2–B2–C2 class of stimuli are presented for Subj. 24. Clusters 1 through 6 and 7 through 9 show data from conditional and simple discrimination trials, respectively. The vertical lines separate data from the baseline and contingency reversal phases. See text for details.

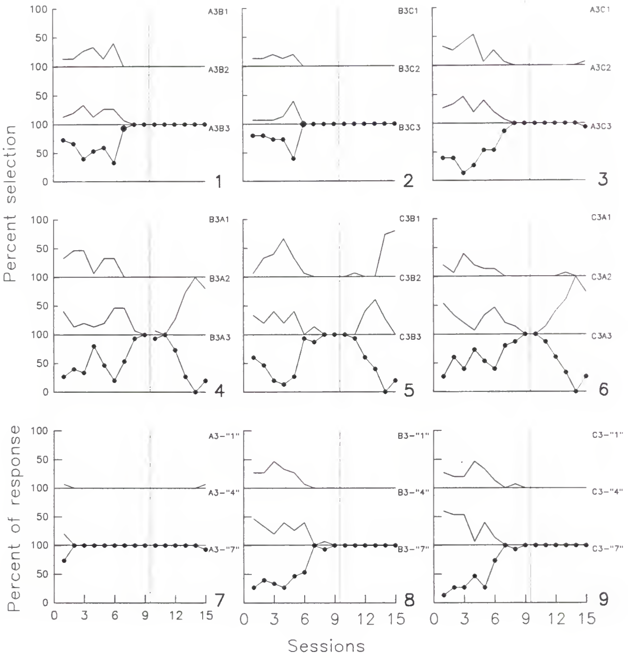

Figure 19. Data for six conditional and three simple discrimination trials for the A3–B3–C3 class of stimuli are presented for Subj. 24. Clusters 1 through 6 and 7 through 9 show data from conditional and simple discrimination trials, respectively. The vertical lines separate data from the baseline and contingency reversal phases. See text for details.

simple discrimination trials involving the A1, B1, and C1 stimuli.

Performance on the Reinforced Conditional Discrimination Trials

Clusters 1 and 2 on Figures 11 through 19 present data from the trained conditional discrimination trials. An open circle around the filled symbol in these clusters marks the session during which the original relation was acquired. As for all of the subjects in Experiment 1, acquisition of original relations during this experiment occurred in two distinct stages. The first stage was characterized by the development of control by the compound stimulus consisting of the prompt and the experimenter-designated correct comparison. All three subjects chose the compound stimulus exclusively by the end of the first session. The second stage was characterized by the development of conditional control by the sample over comparison choices indicated by selection of the experimenter-designated correct comparison stimuli prior to the onset of the prompt. This point will define the acquisition of the original relations. Clusters 1 and 2 on each figure show that each of the subjects acquired the original relations within 1-7 sessions--2 sessions for Subject 18 (Clusters 1& 2, Figures 11 through 13), six sessions for Subject 23 (Clusters 1 & 2, Figures 14 through 16) and seven sessions for Subject 24 (Clusters 1 & 2, Figures 17 through 19).

Performance on the Derived Conditional Discrimination Trials

Clusters 3 through 6 on each figure present data from each of two symmetry (Clusters 4 & 5), one transitivity (Cluster 3) and one symmetrical-transitivity (Cluster 6) trial types for one putative class of equivalent stimuli. Each of the subjects responded in a manner consistent with the development of equivalence relations among the stimuli within 4 to 9 sessions--Subject 18's performance was equivalence-consistent by Session 4 (Clusters 3 through 6, Figures 11 through 13); Subject 23's by Session 8 (Clusters 3 through 6, Figures 14 through 16), and Subject 24's by Session 9 (Clusters 3 through 6, Figures 17 through 19). For each subject, there was a lag between the acquisition of the original relations, and the development of equivalence-consistent responding. Compare, for example, Cluster 2 to Cluster 5 on Figure 11 (Subject 18), Figure 14 (Subject 23) and Figure 17 (Subject 24).

The reversal of contingencies for the A1:B1 and A2:B2 trial types produced similar results for all subjects on the reinforced conditional discriminations and mixed results on the derived conditional discriminations. Each subject persisted in his/her pattern of comparison selections for a few sessions after the contingencies were reversed despite a decrease in the amount of money earned per session. Subject 23 persisted for one session, Subject 18 for three sessions, and Subject 24 for four sessions before acquiring the new conditional discriminations. The effects of the contingency reversal on derived conditional discrimination trials were different for each subject. For Subject 18, performance on some of the derived conditional discriminations remained consistent with the original pattern (A1:C1 - Cluster 3, Figure 11; C1:A1 - Cluster 6, Figure 11; both B2:A2 and C2:B2 - Clusters 4 and 5, Figure 12; B3:A3 - Cluster 4, Figure 13; and A3:C3 - Cluster 3, Figure 13) but fell to approximately chance levels of accuracy on the remaining trial types. His performance on the conditional discriminations involving the A3, B3 and C3 stimuli was also disrupted.

Subject 23, on the other hand, showed complete realignment on derived conditional discrimination trials such that his performance was consistent with the new equivalence relations by the second session after reversal. His performance on the conditional discrimination trials involving the A3, B3, and C3 stimuli was unaffected. Subject 24's performance on all derived trial types was disrupted prior to a change in the original relations (compare performance on original relations - Clusters 1 & 2 - to performance on derived relations - Clusters 3 through 6 on Figures 17 through 19). Acquisition of the new conditional discriminations by Session 5 was followed by the realignment of comparison choices on transitivity trials (Cluster 3, Figures 17 and 18) after two sessions. Performance on both of the symmetry and the symmetrical-transitivity trial types, however, was characterized by a bias toward the selection of the comparison stimulus from Set 3 (see bottom panels of Clusters 4 through 6 on Figures 17 through 19).

Performance on Successive Discrimination Trials

Cluster 7 on each figure presents acquisition data for the trained simple discriminations. These graphs show that each subject acquired the simple discriminations within a few sessions. For Subject 18 and 24, the simple discriminations were acquired within 2-3 sessions (Cluster 7 on Figures 11 through 13 (S18) and Figures 17 through 19 (S24). For Subject 23, these discriminations developed across several sessions--by the end of Session 2 for A1 (Cluster 7, Figure 14), by the end of Session 3 for A3 (Cluster 7, Figure 16) and by the end of Session 5 for A3 (Cluster 7, Figure 15). Clusters 8 and 9 on each figure show the distribution of responses in the presence of B1 and C1, respectively. These data show that, for all subjects, the stimulus functions established for the A1, A2, and A3 stimuli extended to the B and C stimuli that were members of the same equivalence class in the absence of reinforcement (see Clusters 8 and 9 on Figures

11 through 19). The relationship between equivalence-consistent responding and the extension of stimulus function is described in more detail below.

The reversal of contingencies during the discrimination segment entailed reversing the programmed contingencies on trials with A1 or A2 presented as the discriminative stimulus--reinforcing the sequence [Space Bar - 4 - Enter] in the presence of A1 and [Space Bar - 1 - Enter] in the presence of A2. The data presented to the right of the vertical line show discrimination performance following contingency reversal. The latter part of Cluster 7 (Figures 11, 12, 14, 15, 17, and 18) shows the reacquisition data for each of two simple discriminations for all subjects.

These figures show that Subject 23 (Cluster 7, Figures 14 and 15) and Subject 24 (Cluster 7, Figures 17 and 18) relearned the new discriminations within 1 session and Subject 18 (Cluster 7, Figures 11 & 12) relearned the discrimination by the fourth session after reversal. For Subject 18, Clusters 8 and 9 on Figure 11 show that the subject began to emit "4" in the presence of B1 and C1 on greater than 80% of the trials by Sessions 4 and 2, respectively. Clusters 8 and 9 on Figure 12 show that the subject began pressing "1" in the presence of B2 and C2 on greater than 80% of the trials by Sessions 7 and 4 respectively. For Subject 23, Clusters 8 and 9 on Figures 14 and 15 show that the subject continued to press "1" in the presence of B1 and C1 and "4" in the presence of B2 and C2 for the duration of the condition despite the fact that he was pressing "4" in the presence of A1 and "1" in the presence of A2 nearly exclusively by the second session. For Subject 24, Clusters 8 and 9 on Figures 17 and 18 show that the subject pressed "4" in the presence of B1 and C1 and "1" in the presence of B2 and C2 on greater than 85%

of the trials by Session 2. The discriminative functions of B1, C1, B2, and C2 abruptly changed during Session 5. Finally, Clusters 7, 8, and 9 on Figures 12, 15, and 18 show that none of the subjects' performance on the A3, B3, or C3 trials was affected by the contingency manipulations.

In sum, these data show that all three subjects acquired the simple and conditional discriminations in a few sessions. The data also show that all subjects began to respond in a manner consistent with the development of equivalence relations a few sessions after acquisition of the original relations. Further, these data show that the discriminative functions established for one member of an equivalence class extended to other members within that class in the absence of reinforcement. With respect to the conditional discrimination trials, the reversal of contingencies produced a complete realignment of comparison choices for one subject (S 23), a partial realignment for another (S 24) and no realignment for the third subject (S 18).

Relations Between Equivalence-consistent Responding and the Extension of Stimulus Functions

An important benefit of this procedure was the ability to track the development of equivalence-consistent responding and the extension of stimulus function together over time. For Subject 18, the change in the distribution of responses on the successive discrimination probe trials was coincident with changes in performance on the derived conditional discrimination trials (compare the first parts of Clusters 4 and 8 and the first parts of Clusters 5 and 9 on Figures 11 through 13). In other words, the extension of stimulus functions occurred during the same sessions as the development of equivalence-consistent responding.

Following the reversal of contingencies, Subject 18 began pressing "4" in the presence of A1 during the first session (Cluster 7, Figure 11). During the equivalence segments, he continued to select B1 given A1 and B2 given A2 for three sessions (Cluster 1, Figure 11). Clusters 8 and 9 on Figure 11 show that the subject pressed "4" in the presence of B1 and C1 during this time. Cluster 7 on Figure 12 shows that the subject began pressing "1" in the presence of A2 immediately following reversal. Clusters 8 and 9 on this figure show that the subject was also more likely to press "1" in the presence of B2 and C2. In other words, the changed discriminative functions of A1 and A2 were seen to extend in accordance with the equivalence classes established prior to the reversal of contingencies. The reacquisition of changed original relations (Clusters 1 and 2, Figures 11 and 12) failed to produce choices consistent with reorganized equivalence classes (see Clusters 3 through 6 on Figures 11 and 12), however, and also failed to produce any change on simple discrimination probe trials (Clusters 8 and 9, Figures 11 and 12). These data show that, for Subject 18, the extension of stimulus functions was related to the development of equivalence relations prior to the reversal of contingencies and that changes in the discriminative properties of A1 and A2 following contingency reversal extended to other stimuli in the original equivalence class. The data further show that the reacquisition of changed original relations failed to produce equivalence-consistent choices on the derived conditional discrimination trials or a realignment of the discriminative properties of the stimuli in the simple discrimination task.

For Subject 23, the trained stimulus functions of A1, A2, and A3 were seen to extend to the other stimuli in the equivalence classes several sessions after responding on the conditional discrimination trials had become equivalence-consistent (compare the first parts of Cluster 4 to Cluster 8 and Cluster 5 to Cluster 9 on Figures 14 through 16). He reacquired the changed original relations during the second session following contingency reversal and showed near perfect accuracy on all derived conditional discrimination trials indicating the simultaneous development of equivalence relations (see Clusters 1 through 6 on Figures 14 and 15). His performance on the simple discrimination trials also indicated the extension of changed stimulus functions on all simple discrimination probe trials (compare Cluster 7 on Figure 14 with Clusters 8 and 9 on Figure 15 and Cluster 7 on Figure 15 with Clusters 8 and 9 on Figure 14). These data show that, for Subject 23, the stimulus functions of A1 and A2 extended in accord with the original and realigned equivalence relations.

For Subject 24, the functions of A1 were seen to extend to B1 by Session 6 although the subject did not begin selecting A1 given B1 (symmetry) consistently until Session 7. Similarly, Subject 24 began pressing "1" in the presence of C1 on greater than 80% of the trials by Session 6 although consistently accurate performance on C1-B1 symmetry, A1-C1 transitivity and C1-A1 symmetrical transitivity trials was not seen until Session 9 (compare the first parts of Cluster 4 to Cluster 8 and the first parts of Cluster 5 to Cluster 9 on Figure 17). This extension of stimulus function prior to the development of equivalence-consistent responding was also seen for the B3 and C3 stimuli (compare Cluster 4 to Cluster 8 and Cluster 5 to Cluster 9 on Figure 19). The discriminative property of A2, however, extended to B2 and C2 during Sessions 6 and 7, respectively--the same sessions during which her performance on the derived conditional discrimination trials became equivalence-consistent (compare the first parts of Cluster 4 to Cluster 8 and Cluster 5 to Cluster 9 on Figure 18).

Following the reversal of contingencies, Subject 24's choices on original relations trials remained consistent with the prereversal pattern for four sessions (Cluster 1 on Figures 17 and 18) and the changed discriminative properties of A1 and A2 were seen to extend to the B and C stimuli related via equivalence classes established prior to reversal (compare data from the reversal phase on Cluster 7 to Clusters 8 and 9 on Figures 17 and 18). Beginning with the fifth session following contingency reversal, the subject reacquired the changed original relations (Cluster 1, Figures 17 and 18) and began selecting B2 given A1 and B1 given A2. During the same session, her choices on the simple discrimination trials began a trend toward realignment in accord with the changed conditional discrimination contingencies despite the fact that her performance on the derived conditional discrimination trials failed to indicate the development of equivalence relations. These data show that, under the original contingencies, the extension of stimulus functions occurred prior to the development of equivalence relations. Following the reversal of contingencies, the data show that extension of stimulus functions was consistent with the trained, overlapping conditional discriminations in the absence of responding indicative of equivalence class formation.

Taken together, these data show that, prior to the reversal of contingencies, extension of stimulus functions was sometimes seen (a) following the development of equivalence relations (Subject 23, Figures 14-16), (b) during the development of equivalence relations (Subject 18, Figures 11-13 and Subject 24, Figure 18), and (c) prior to the development of equivalence relations (Subject 24, Figures 17 and 19).

Following the reversal of contingencies, Subject 18 and Subject 24 (during the first four sessions following reversal) showed the extension of stimulus functions in accord with equivalence relations established prior to the reversal of contingencies. Subject 23 showed the simultaneous acquisition of conditional and simple discriminative functions and the extensions of those functions following contingency reversal. During the last two sessions of the experiment, Subject 24 showed the extension of stimulus functions in accord with the trained overlapping conditional discriminations in the absence of choices indicative of equivalence class formation.

Discussion

Performance in the Equivalence Segment

All 3 subjects acquired the original relations under these conditions. As in Experiment 1, the acquisition of original relations occurred in two distinct stages: (a) the development of control by the compound stimulus comprised of the experimenter-designated correct comparison and the prompt, and (b) the development of conditional control over comparison selection by the presence of particular samples. All 3 subjects also showed the development of equivalence relations. Following the reversal of contingencies, all 3 subjects reacquired the changed original relations. Two of the 3 subjects showed complete (Subject 23) or partial (Subject 24) realignment of responses on the derived conditional discriminations in a manner consistent with the formation of new equivalence classes. Subject 24's data following the reversal of contingencies are particularly interesting because she showed realignment of selections on the derived transitivity trials but not on the symmetry or symmetrical-transitivity trials--a result that is inconsistent with prior research involving contingency reversals (Pilgrim & Galizio, 1990, 1995; see Pilgrim & Galizio, 1997 for a discussion). Otherwise, the results are in general agreement with previously reported findings.

Performance in the Discrimination Segment

All 3 subjects acquired the successive simple discriminations within a few sessions. All 3 subjects also showed the emergent extension of stimulus functions to stimuli related via the trained conditional discriminations under the original contingencies. Following the reversal of contingencies in the presence of A1 and A2, all 3 subjects showed the extension of changed discriminative properties. These results are in general agreement with the findings from previous research in showing that simple discriminative functions established for some stimuli extended to other stimuli that were related via equivalence (Barnes & Keenan, 1993; Gatch & Osborne, 1989; Lazar, 1977) among others.

Taken together, these results suggest that the modifications in the equivalence preparation and the interlacing of simple and conditional discrimination did not appreciably alter the phenomena of interest. As such, this procedure appears to be a viable means of investigating the development and time course of the relationship between equivalence relations among stimuli and the extension of stimulus functions across those stimuli. The implications of the observed relationships are discussed next.

Relations Between the Development of Equivalence Relations and the Extensions of Stimulus Function

All 3 subjects engaged in conditional discriminations indicative of equivalence relations during the first phase of the experiment and showed the emergent extension of stimulus functions to the stimuli related via equivalence. Although in general agreement with the findings cited earlier, a closer look at the time course for each of the phenomena reveals some interesting details which bear on the potential mediating role of equivalence classes in the extension of function. For Subject 18, the extension of stimulus functions occurred during the same sessions as equivalence-consistent responding. For Subject 23, however, accuracy on the discrimination probe trials lagged a few sessions behind accuracy on the derived conditional discrimination trials. That is, stimulus functions were seen to extend a few sessions after equivalence-consistent responding became likely. Most interestingly, for Subject 24, the extension of simple discriminative functions was seen before the subject's performance on conditional discrimination trials became equivalence-consistent.

Following contingency reversal, for Subject 18 and 24, the changed discriminative properties of A1 and A2 were seen to extend in accord with the equivalence relations established prior to the reversal of contingencies during the same sessions that conditional discrimination choices remained consistent with prereversal contingencies. For Subject 18, reacquisition of the original relations failed to produce equivalence-consistent choices on the conditional discrimination trials or a realignment of the extension of stimulus functions. For Subject 24, reacquisition of the original relations produced a realignment of choices only on the transitivity trial types and a realignment of the extension of simple discriminative functions. For both subjects, disruptions in the conditional relations embodied in the A3-B3-C3 class did not affect the trained or extended stimulus functions of these stimuli during the simple discrimination trials. For Subject 23, the acquisition of the changed original relations realigned choices on the derived conditional discrimination trials indicating the reorganization of equivalence relations. The changed discriminative properties of A1 and A2 were also seen to extend to the other stimuli related via equivalence.

The close temporal relationship between the development of equivalence relations and the extension of stimulus functions seen for Subject 18 (prereversal) and Subject 23 (postreversal) suggests that equivalence class formation and extension of stimulus function are indeed closely related. This observation is further supported by the correlation between choices on conditional discrimination trials and simple discrimination trials seen for Subject 18 and 24 during the first three to five sessions of the postreversal phase. On the other hand, the lag between the development of equivalence relations and the extension of stimulus functions seen for Subject 23 suggests at least a partial dissociation between the phenomena. This conclusion is further supported by the extension of functions seen prior to equivalence-class formation (Subject 24, prereversal phase) and in the absence of equivalence class formation (Subject 24, last few sessions of postreversal phase). Taken together, these results challenge the notion that equivalence relations between stimuli are behavioral prerequisites for the extensions of stimulus functions across those stimuli.

GENERAL DISCUSSION

The goal of Experiment 1 was a more precise characterization of the development of equivalence relations, particularly, the relationship between the acquisition of original relations and the development of equivalence relations. The results from Experiment 1, and the equivalence segments from Experiment 2, show that (a) the original relations were acquired at different times, and (b) there was a lag between the acquisition of original relations, the putative basis for the development of equivalence classes, and the emergence of behavior indicative of those classes. These data cast doubt on the suggestion that stimuli related via conditionality are also immediately related via equivalence (Sidman, 1986, 1990). Specifically, the lag in accurate responding suggests that the behavioral prerequisites for relations of conditionality and equivalence are not always identical, though they sometimes can be.

The results also show that (a) the component stimulus control relations (symmetry, transitivity and symmetrical transitivity) that define stimulus equivalence classes (Sidman & Tailby, 1982) emerged at different times following the acquisition of the original relations, and (b) the reversal of contingencies for two of the six original relations affected the derived stimulus-control relations differently. These data show that the procedurally specifiable stimulus control relations that operationally define the properties of an equivalence relation (Saunders & Green, 1992) react differently to perturbations of the trained conditional discriminations on which they are based. These findings call into question the assumed integrated nature of equivalence relations, suggesting instead that the typical equivalence findings may represent the concatenation of separate stimulus-control relations as opposed to responding under control of a single integrated equivalence relation (Sidman, 1994; see Pilgrim & Galizio, 1997; Wilson & Hayes, 1996 for discussions).

The goal of Experiment 2 was a more precise characterization of the role of equivalence classes in the unreinforced extensions of stimulus functions. The results show that the development of equivalence relations was neither necessary nor sufficient for the extension of stimulus functions. The simultaneous development of equivalence relations and extension of stimulus function seen for Subject 18 (prereversal) and Subject 23 (postreversal) is consistent with the commonly held view that equivalence relations mediate the extension of stimulus functions. The lag between the development of equivalence relations and the extension of function seen for Subject 23 (prereversal), however, show that equivalence relations, per se, are not sufficient to produce extension of function. This result also challenges the claim that the extension of stimulus function is a defining feature of equivalence classes (cf. Hayes, 1991; Barnes, 1994). That extended stimulus functions were sometimes maintained in the absence of equivalence relations (Subject 18) or that extension of stimulus function sometimes occurred prior to responding indicative of equivalence relations (Subject 24) suggest that equivalence classes are not necessary for the extension of stimulus functions (cf. Catania et al., 1989; Barnes & Keenan, 1993).

From a procedural perspective, the formation of equivalence classes can be viewed as simply another kind of extension of function--one in which the trained conditional and discriminative properties of stimuli are seen to become interchangeable. Conceptualizing equivalence-consistent responding itself as one kind of extension of function permits a different view of the role of equivalence classes in the extension of stimulus functions. From this perspective, establishing some functions for stimuli (say, conditional and discriminative functions) may, under certain conditions, be sufficient to produce interchangeability of those stimulus functions as well as the extension of other (eliciting, consequential, contextual) stimulus functions. As a case in point, consider Subject 24's data from the last two sessions in the reversal phase. These data show that the reacquisition of trained relations was sufficient to produce extension of stimulus functions in the absence of responding indicative of symmetry or symmetrical transitivity.

This perspective also permits a reinterpretation of earlier results showing the extension of stimulus functions prior to the documentation of equivalence relations (see Catania et al., 1989; deRose, McIlvane, Dube, Galpin, & Stoddard, 1988; Lazar, 1977; Wulfert & Hayes, 1988). Specifically, these experiments showed the extension of stimulus functions to stimuli related via conditionality prior to the presentation of testing trials to document the existence of equivalence relations. Rather than questioning the necessity of equivalence relations in the extension of stimulus functions, however, it was assumed that equivalence classes were formed (though undocumented) via the establishment of the conditional relations, and that these equivalence classes then mediated the extension of stimulus functions. The results from Experiment 1 and the equivalence segment from Experiment 2, however, show that the development of conditional relations does not automatically lead to the development of equivalence relations. The data from Experiment 2 provide unequivocal evidence that equivalence relations are not necessary for the extension of stimulus functions.

The results from these experiments highlight the benefits of the procedures used in allowing a more fine-grained analysis of the relationships between the different stimulus control relations involved in the acquisition of trained conditional and simple discriminations and the emergent interchangeability or extension of those functions. By simultaneously tracking the development of each of these relations together over time, the present procedures remove the need to speculate about the relation between them. Instead, they allow for direct measurement of each of the relations and the dependencies between them.

It is important to note that the findings of these experiments were generally consistent with results from previous studies. The more detailed analysis afforded by the present procedures, however, strongly suggest that the behavioral prerequisites for relations of conditionality and equivalence are not identical, that the stimulus control relations comprising equivalence classes can become independent of one another, and that the relationship between equivalence class development and the extension of stimulus functions is more complex than previously realized. Taken together, these data raise questions of central importance concerning the status of the equivalence relation as an integrated, fundamental process that underlies other behavioral capacities.

APPENDIX
INSTRUCTIONS

Instructions for Experiment 1: Your task in this experiment involves responding to some pictures you will see on the screen. Throughout the experiment, you are to respond to these pictures using only the 4-arrow keypad and the Enter key. The program will inform you when the session is finished. Throughout the session, it will be important for you to hold this switch pressed with your nonpreferred hand. Once we begin, I will not be able to answer any questions until the end of the experiment. Do you have any questions before you start? *Before we begin, I have one additional instruction for you: There is always a correct answer for every problem.* (Note: The italicized phrases were added for Subjects 9, 12, and 13).

Instructions for Experiment 2: Your task in this experiment involves responding to some pictures you will see on the screen. Each session will consist of two different kinds of tasks. Throughout the task involving multiple pictures, you are to respond using only the 4-arrow keypad and the Enter key. Throughout the task involving single pictures, you are to respond to the pictures by hitting the space bar and one of the number keys followed by the Enter key. Please remember that there is always a correct answer for every problem. The program will inform you when the session is finished. Throughout the two tasks, it will be important for you to hold this switch pressed with your nonpreferred hand. Once we begin, I will not be able to answer any questions until the end of the experiment. Do you have any questions before you start?

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BIOGRAPHICAL SKETCH

I earned a bachelor's degree in applied arts and sciences with a professional concentration in Behavior Analysis in 1989, under the guidance of Dr. Janet K. Ellis. I was then admitted to the newly developed master's degree program at the University of North Texas and earned a Master of Science degree (in Behavior Analysis) in 1994 under the guidance of Dr. Sigrid S. Glenn. This dissertation is submitted toward completion of requirements of a doctoral degree earned under the guidance of Dr. Timothy D. Hackenberg at the University of Florida. The degree is to be awarded in 2000.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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